

A FOUR-POINT PROBE FOR RESISTIVITY MEASUREMENTS OF SEMICONDUCTORS

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ABSTRACT. The constructional details of a four-point probe for resistivity determination of semi-conductors are given. The method for electrolytic pointing of tungsten wires used in the probe is also described.

INTRODUCTION

The knowledge of resistivity of semiconductors is essential in determining their suitability for fabricating semiconductor devices and hence the need arises for making accurate measurement of resistivity. The rectifying nature of the contacts and the minority carrier injection by one of the current contacts are some of the faults generally encountered in the conventional methods. Valdes (1954) has described a method in which these difficulties have been overcome and offers in addition several other advantages. The one principal advantage is that one does not require any special specimen geometry and permits measurement of resistivity of small volumes within bigger bulk semiconducting material.

The method consists in placing four sharp metal points in a line on a flat surface of the semiconducting material to be measured, passing a current, I (amp), through the two outer electrodes and measuring the voltage, V (volts), across the two inner ones (Fig. 1). Valdes (1954) has discussed the various modes of place-

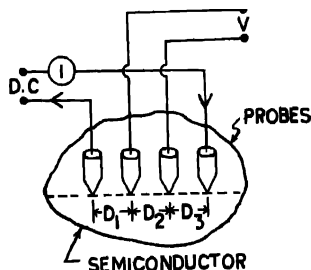


Fig. 1. Arrangement for four probe resistivity measurement

ment of probes and has shown that with certain assumptions, the resistivity in the case of a large sample is given by

$$\rho = \frac{V}{I} \cdot \frac{2\pi}{\left(\frac{1}{D_1} + \frac{1}{D_3} - \frac{1}{D_1 + D_3} - \frac{1}{D_2 + D_3} \right)} \quad \dots (1)$$

where ρ = resistivity, in ohm-cm.
 D_1, D_2, D_3 = point spacing, in cm.

When the probe spacing is equal, that is $D_1 = D_2 = D_3$, the above equation simplifies to

$$\rho = 2\pi D \cdot V \quad \dots (2)$$

THE PROBE UNIT

Because of the frequent need for making resistivity measurements, the probe unit should be so designed as to permit making quick measurements and, furthermore, the whole unit should be simple in construction. Such a unit has been constructed in this institute and the details are reported here (Fig. 2). The unit is similar to one reported by MacDonald *et al*, (1953) but differs in the method of varying the contact pressure of the metallic points against the semiconductor.

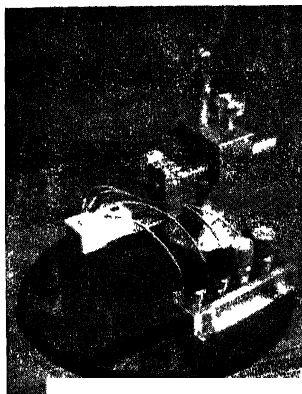


Fig. 2 Photograph of four-probe resistivity measuring instrument.

The unit consists of two parts : (i) A head which supports the tungsten wires and (ii) a pivotal arrangement by means of which pressure contacts on the semiconductor surface is achieved.

The head is made of Teflon because of its high resistance, low humidity absorption, low coefficient of friction, and excellent machining properties. It has four equally spaced holes into which tight fitting 20 mil (0.020 inch) tungsten wire have been inserted. The spacing between the tungsten points is 1.630 ± 0.015 mm,

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The head is mounted on an arm which is hinged at the opposite end (Fig. 3). A smooth and regular variation of contact pressure of tungsten wires against the semiconductor surface is manipulated by means of a screw head. MacDonald

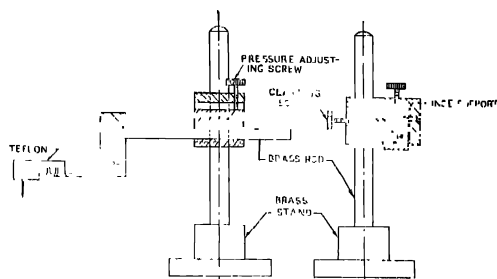


Fig. 3. Line diagram of the probe unit.

et al (1953) have used in their instrument a sliding weight on the hinged arm to vary the contact pressure. The arm supporting the head is in turn mounted on and can slide along a vertical supporting rod. This arrangement facilitates working with samples of different sizes.

ELECTROPPOINTING OF WIRES

The tungsten wires in the Teflon head are to be provided with conical points. To obtain wires of equal length and sharpness, an electrolytic technique for pointing, described by Pfann (1947), is employed. By this method it is possible to produce points of any desired degree of sharpness on tungsten and, furthermore by a suitable choice of electrolytes, cathode materials and working voltages, the method can be extended to a variety of metals. The electropointing circuit is shown in Fig. 4, which is self explanatory.

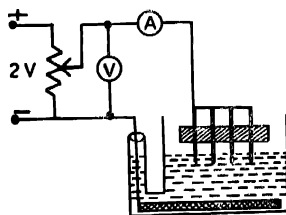


Fig. 4. Electropointing circuit.

The electrolyte is an aqueous solution of potassium hydroxide. While the concentration of potassium hydroxide is not critical and can be varied between 10% and 50%, a 38% concentration has been used in the present work.

The pointing time and the shut off current are only affected by the concentration, the pointing time being smaller for higher composition. The volume of the electrolyte is also immaterial in this particular case. A small quantity of copper in the form of cupric chloride is added to the electrolyte. The quantity of cupric chloride is also variable but the copper content should not exceed 1.1 mg per cc. The purpose of adding copper is two fold. Firstly, it makes the meniscus cling firmly to the wire in position which could otherwise be disturbed due to slightest vibration and secondly, to help in reforming the cathode coating rapidly which is depleted during pointing action.

The cathode is a copper sheet which is previously aged for several days in the electrolyte to form an appreciable coating of copper oxide, so as to make the cathode self-depolarizing. This is desirable to prevent gassing during pointing which may otherwise disturb the menisci, as is usually the case with clean copper cathode. To conserve the cathode coating, it is necessary to maintain an upper current limit. This is done by keeping the ratio of wetted tungsten area to cathode area below 0.01.

The arm holding the Teflon head is lowered until the wires are immersed in the electrolyte to a depth of about 5 mm. The positioning of the vessel containing electrolyte is essential to obtain wires of same length after pointing.

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